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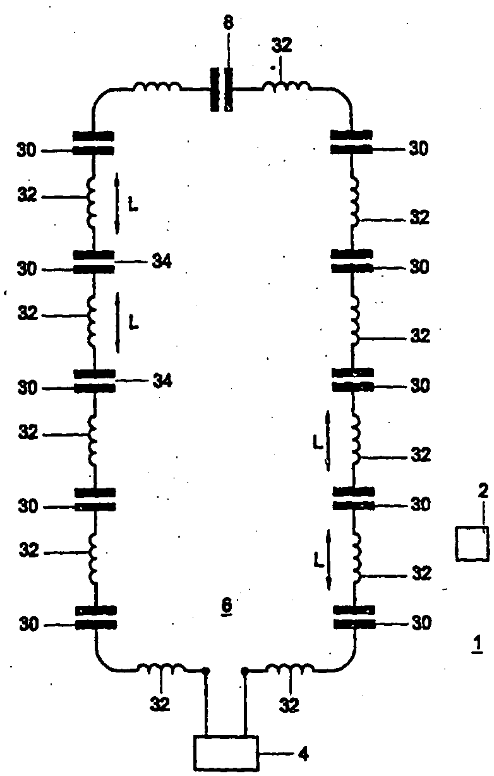
(54) Title: SYSTEM FOR DETECTING AND OPTIONALLY COMMUNICATING WITH TRANSPONDERS SUCH AS ANTITHEFT TRANSPONDERS AND IDENTIFICATION TRANSPONDERS

(57) Abstract

The invention relates to a system for detecting and optionally communicating with transponders comprising a resonant circuit, such as antitheft transponders and identification transponders, comprising a transmitter and receiver device, an antenna configuration coupled with the transmitter and receiver device, comprising at least one loop antenna for radiating an electromagnetic interrogation field, and at least one transponder of which the resonant circuit is caused to resonate when the transponder is introduced into the interrogation field, the transmitter and receiver device being further arranged for detecting when the resonant circuit resonates. According to the invention, the loop antenna is interrupted at a plurality of points by capacitors included in the loop antenna at those points, so that the loop antenna is made up of electrically conductive loop parts, with the loop parts and capacitors connected in series.



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Title: System for detecting and optionally communicating with transponders such as antitheft transponders and identification transponders.

This invention relates to a system for detecting and optionally communicating with transponders comprising a resonant circuit, such as antitheft transponders and identification transponders, comprising a transmitter and receiver device, an antenna configuration coupled with the transmitter and receiver device, comprising at least one loop antenna for radiating an electromagnetic interrogation field, and at least one transponder of which the resonant circuit is caused to resonate when the at least one transponder is introduced into the interrogation field, the transmitter and receiver device further being arranged for detecting when the resonant circuit resonates.

The invention also relates to a transmitter and receiver device coupled with an antenna configuration of that system.

Such systems are known per se. For inductive communication, identification and detection systems, use is made of loop antennas for generating the electromagnetic interrogation field. This electromagnetic interrogation field is necessary to interrogate a transponder and often also to feed it energetically. This transponder transmits a reply signal, which can be received by means of the same loop antenna or by means of a second loop antenna. The interrogation fields in question can have different frequencies. Examples of known operating frequencies are 120 kHz, 3.25 MHz, 6.78 MHz, 8.2 MHz, 13.56 MHz and 27.12 MHz. Higher operating frequencies are often desired in view of an attendant rise in insensitivity to interference. Examples of inductive systems utilizing these loop antennas are described in patent applications NL 9202158 and EP 0,608,961.

In the known systems, at higher frequencies, the dimensions and the number of turns are limited by the total

length of the loop of the loop antenna. Further, it is well known that on an axis of the loop antenna the field strength decreases very strongly with the distance to the plane of the loop antenna as soon as this distance exceeds half the diameter of the loop antenna. If it is to be possible for a transponder to be read out in a predetermined detection area, a magnetic field strength will have to be sufficiently high at all points in that detection area to enable the transponder to function. In combination with the limited dimensions of the loop antenna, this means that the magnetic field strength closer to the loop antenna must be very much greater than at positions in the detection area located at a greater distance from the loop antenna. Strength ratios of a factor of 10 or more are quite common. These excessive magnetic and/or electric field strengths at the present higher operating frequencies can be threatening to people who carry in them an implanted pacemaker or any other medical implant. Also, excessive magnetic and electric field strengths may enter into such interaction with the tissue of the human body as to involve an adverse influence.

It is one object of the invention to remove the limitations in dimensions of inductive loop antennas for higher frequencies. It is another object of the invention to create the possibility of also packing inductive loop antennas for higher frequencies in various non-conductive materials and constructions without the latter seriously influencing operation. It is a further object of the invention to make possible an antenna configuration such that a detection area can be properly covered for detecting the transponder without excessive magnetic and/or electric field strengths occurring there at any point, which field strengths could be disadvantageous to those carrying medical implants or which field strengths enter into such interaction with the tissue of the human body as to involve an adverse influence.

The system according to the invention is characterized in that the loop antenna is interrupted at a

plurality of points by capacitors included in the loop antenna at these points, so that the loop antenna is made up of electrically conductive loop parts, with the loop parts and capacitors connected in series.

The invention is based on the insight that the reactance of a self-inductance, X_L, is opposite to the reactance of a capacitance X_C. That means that if a self-inductance element and a capacitance element are connected in series, the reactances of the two elements partly compensate each other. At one frequency this compensation is even complete.

In the loop antenna of the system, this principle is utilized by interrupting the loop at a number of points and connecting it through a series capacitor. The capacitors must then have that value at which the reactances thereof wholly or partly compensate the reactances of the self-inductance of the intervening loop parts.

In particular, the electromagnetic interrogation field comprises a frequency f, while a loop part located between two capacitors has a dimension smaller than c/2*pi*f, where c is equal to the speed of light.

In this way, at all times a value for the capacitance of the capacitors can be chosen such that the loop antenna will not start to behave as a transmission line. More particularly, each of the loop parts located between two capacitors has dimensions smaller than c/2*pi*f.

According to a preferred embodiment, the electromagnetic interrogation field comprises a frequency f, while the capacitors have such capacitive values that at the frequency f the reactance of the capacitors and the reactance of self-inductances of the loop parts located between the capacitors compensate each other.

The antenna configuration can function as transmitting and reception antenna, and in particular a single antenna loop functions as transmitting and reception antenna. It is also possible, however, that the antenna

configuration comprises at least one first loop antenna which, in use, functions as a transmitting antenna and at least one second loop antenna which, in use, functions as reception antenna.

According to a highly advanced embodiment, the loop antenna consists of a cable provided with a plurality of conductive loop parts and capacitors, with the conductive loop parts and the capacitors connected in series, such that two adjacent conductive loop parts are connected with each other through one of the capacitors.

Preferably, the cable is provided with a sheath in which the conductive loop parts and the capacitors are included.

The invention will presently be further explained with reference to the drawings, wherein:

Fig. 1 shows a system for detecting transponders fitted with a loop antenna according to the prior art;

Fig. 2 shows a schematic representation of spread self-inductances and capacitances in the loop antenna according to Fig. 1;

Fig. 3 shows the current and voltage distribution according to an extreme example of the loop antenna according to Fig. 1 in the form of an electric half wave dipole;

Fig. 4 shows a top plan view of a passageway for persons, having on opposite sides loop antennas with associated magnetic field lines of the system according to Fig. 1;

Fig. 5 shows a system for detecting transponders according to the invention;

Fig. 6 shows a top plan view of a passageway for persons, fitted with a loop antenna of the system according to Fig. 5; and

Fig. 7 shows a cable from which a loop antenna according to Figs. 5 and 6 can be constructed.

In Fig. 1, reference numeral 1 designates a system for detecting transponders 2 and optionally communicating

with transponders 2 such as antitheft transponders and identification transponders. These transponders are known per se and comprise a resonant circuit known per se. The system comprises a transmitter and receiver device 4 and an antenna configuration 6 coupled with the transmitter and receiver device, which antenna configuration 6 comprises at least one loop antenna for radiating an electromagnetic interrogation field. In this example, the antenna configuration consists of a loop antenna with a loop comprising a single turn.

The system further comprises at least one transponder 2 of which the resonant circuit is caused to resonate when the transponder 2 is introduced into the interrogation field. The transmitter and receiver device 4 is further arranged for detecting when the resonant circuit resonates.

For relatively low operating frequencies, such as 120 kHz, the loop antenna mostly consists of many turns and the dimensions can be more than two by two meters.

For the medium frequencies, such as 8.2 MHz, the loop antenna consists of one turn (as shown in Fig. 1) having smaller dimensions, for instance about 0.5 by 1.4 meters.

For the higher frequencies, such as 13,56 MHz, the dimensions are limited even more and the loop antenna likewise consists of one turn (as shown in Fig. 1) having dimensions of, for instance, about 0.5 by 1.0 m.

At higher frequencies, the dimensions and the number of turns are limited by the total length of the loop.

The loop antenna 6, as said, contains one turn and is connected at the top to a capacitor 8, which causes the loop antenna to resonate at the operating frequency f when a transmitted signal is fed to the loop antenna 6 by means of the transmitter and receiver device 4.

In this example, the loop antenna 6 is connected to the transmitter and receiver device 4, with the loop antenna 6 functioning both as transmitting antenna and as reception antenna. This is in contrast to other systems known per se, where the antenna configuration includes two loop antennas,

the first loop antenna being connected with the transmitter and receiver device 4 and functioning as transmitting antenna, while the second loop antenna is connected with the transmitter and receiver device 4 and functions as reception antenna. The problems in the known systems as outlined hereinbelow occur in both types of antenna configurations and will therefore be discussed in more detail only with reference to the example of Fig. 1.

The connecting points 10 of the loop antenna 6 to the capacitor 8 can also be the points with which the loop antenna is connected to the transmitter and receiver device 4, as shown in this example, but this may also be designed in many other ways. The manner of connection to the transmitter and receiver device is not relevant to the invention and is therefore not further considered here. The transmitter and receiver device, too, can be designed in various ways known per se, for instance including separate transmission and reception units. This is not relevant to the invention either and will not be further explained here.

For the relatively low frequency, the loop antenna 6 together with the tuning capacitor 8 forms a resonant circuit consisting of a concentrated self-inductance which is formed by the self-inductance of the conductive loop 12, and of the capacitance of the tuning capacitor.

At higher operating frequencies, the loop antenna starts to exhibit transmission line behavior, which is the result of the fact that the loop antenna consists of a spread self-inductance and a spread capacitance. In Fig. 2 this is depicted schematically.

The consequence of the spread self-inductance and capacitance is that the current through the loop 12 is not of equal magnitude everywhere. In the symmetrical example, as drawn in Fig. 2, at the central bottom junction, opposite the tuning capacitor 8, the alternating voltage is zero and the current is maximal. On both sides of the loop 12 the voltage increases towards the top. As a result, a capacitive current

will start to flow through lateral space capacitances 14 and through mutual capacitances 15. This current reduces the current through the parts of the loop located above these capacitances. Eventually, the current is minimal at the position of the tuning capacitor 8.

An extreme situation arises when the total length of the loop 12 equals a half wavelength associated with the operating frequency. Again, the current is now at a maximum in the middle of the loop, and the total current disappears in the space capacitances. The capacitance of the tuning capacitor has become zero. In Fig. 3, this loop 12 is drawn in extended condition and the resemblance to a half wave dipole antenna is clear. Also drawn in this figure are the distribution of the current I (curve 18) and the distribution of the voltage V (curve 20) of the dipole antenna 12.

Regarding the use of an inductive loop antenna of a length not negligibly small with respect to a half wavelength $\gamma/2$, the following disadvantages exist:

1. The current is not constant along the circumference. This means that the resulting magnetic field is not uniform but is deformed in that the upper part of the loop contributes less to the field.
2. The tuning capacity 8 will have a low value; the space capacitances 14 and 15 contribute relatively much to the total resonance capacitance. This renders tuning highly sensitive to ambient influences. Nor is it possible anymore to incorporate the loop 12 in materials having a relative permeability >1, unless the dimensions are limited still further. Also, the great influence of the space capacitances renders the loop 11 sensitive to damping through dielectric losses in the material of incorporation. In particular moisture in these materials can have a highly adverse influence on the operation.

3. The relatively small resonance capacitance, together with the datum that the loop antenna consists of a single turn through which flows a high current to be able to achieve the required magnetic field strength, causes great high-frequency voltages to arise across the tuning capacitor, and hence on those parts of the loop antenna adjacent the tuning capacitor.
4. Since the dimensions of the loop are very limited, a loop antenna can only be placed on the side of a passageway.

Fig. 4 shows such a passageway in which arrow 22 indicates the direction of passage. A detection area 24 of the passageway in which it must be possible for a transponder to be detected is hatched. The antenna configuration here comprises two loop antennas 6, 6', which are placed on either side of the passageway and here function as transmitting and reception antennas. The magnetic field lines are designated by 26, and also indicated is the common axis 28 of the loop antennas 6, 6'. It is well known that on the axis of the loop antenna 6, 6', the field strength decreases very strongly with the distance to the plane of the loop antenna as soon as this distance exceeds half the diameter of the loop antenna.

If it is to be made possible for a transponder 2 to be read out, the magnetic field strength in the middle of that passageway will have to be sufficiently high to enable the label to function. In combination with the limited dimensions of the loop 12 of the loop antennas 6, 6', this means that the magnetic field strengths in the middle of that passageway must be sufficiently high to enable the label to function. In combination with the limited dimensions of the loop of the loop antennas 6, 6', this means that the magnetic field strength closer to the loop antennas 6, 6' must be very much greater; strength ratios of a factor of 10 or more are quite common.

Since at the points adjacent the tuning capacitor 8 (see Fig. 1) high voltages arise on the antenna loop, high electric field strengths will also be present in situ.

These excessive magnetic and/or electric field strengths at the present higher operating frequencies can be threatening to people carrying in them an implanted pacemaker or any other medical implant. Also, excessive magnetic and electric field strengths can enter into such interaction with the tissue of the human body as to involve an adverse influence.

It is an object of the invention to remove this limitation in dimensions of inductive loop antennas for the higher frequencies. It is also an object of the invention to create the possibility of also packing inductive loop antennas 6, 6' for higher frequencies in various non-conductive materials and constructions without the latter seriously influencing operation.

Finally, an object of the invention is to make possible an antenna configuration such that a passageway for persons can be largely covered for reading a label without excessive magnetic and/or electric field strengths occurring there, which field strengths could be disadvantageous to the carriers of medical implants, or which field strengths enter into such interaction with the tissue of the human body as to involve an adverse influence.

The invention is based on the fact that the reactance of a self-inductance, X_L, is opposite to the reactance of a capacitance, X_C. That means that if a self-inductance and a capacitance are connected in series, the reactances of the two elements partly compensate each other. At one frequency this compensation is complete, i.e. $X_L = X_C$.

This frequency can be derived from the equation of the absolute values of the two reactances: $2\pi*f*L = I/(2\pi*f*C)$, where f represents the operating frequency of the electromagnetic interrogation field, L the self-inductance and C the capacitance. In the inductive loop

antenna 6', this principle can be utilized by interrupting the loop at a number of points and connecting it through a series capacitor 30. The capacitor must then have that value at which its reactance compensates, at least partly, the reactance of the self-inductance of the intervening loop parts. By selecting the length of the conductive loop parts 32 to be short, the capacitance of the series capacitors 30 is rendered large and hence the influence of the space capacitances 14, 15 small.

In this way, in principle, an infinitely long line of loop parts 32 with intervening, inductive reactance-compensating capacitors 30 can be built up without the reactance of the whole loop becoming high or the loop starting to exhibit transmission line properties.

Fig. 5 schematically shows a loop antenna according to the invention.

In the example of Fig. 5, parts corresponding to Fig. 1 are provided with the same reference numerals. In illustration of the fact that the transmitter and receiver device 4 can also be connected with the loop antenna 6 at a different position, it is presently connected with the loop antenna 6 at a position opposite the capacitor 8. However, this is not essential to the invention.

The loop antenna 6 is therefore interrupted at a plurality of points 34, while capacitors 30 included in the loop antenna at the points referred to are connected in series with the capacitors in the loop antenna. In other words, the loop antenna is interrupted at a plurality of points by capacitors included in the loop antenna at the points referred to, so that the loop antenna is made up of electrically conductive loop parts and the capacitors, with the loop parts and capacitors connected in series.

The impedance of the loop antenna is capacitive for all frequencies below the resonant frequency f and is inductive above it. Only for frequencies where the separate loop parts 32 have dimensions l greater than $\lambda/2\pi$ is it no

longer possible to choose a capacitance such that the loop does not behave as a transmission line anymore. In this example $l < \lambda/2\pi$. Given that $\lambda = c/f$, then $l < c/2*pi*f$.

Accordingly, the electromagnetic interrogation field, i.e. the resonant frequency of the loop antenna 6 with the capacitor 8, comprises a frequency f, while it holds that a loop part 32 located between two capacitors has a dimension l which is smaller than c/2*pi*f, where c is equal to the speed of light. In particular, each of the loop parts located between two capacitors has dimensions smaller than c/2*pi*f.

The table below gives an indication of the relation between the length l of the loop parts 32, each forming a self-inductance L which is indicated in the drawing by the symbol of the coil, and the capacitance of the series capacitors at an operating frequency of 13.56 MHz:

Length l:	1.0	0.75	0.5	0.25	0.1	m
Capacitance C:	138	184	276	551	1378	pF

An additional advantage in the use of a high capacitance value, and hence short loop parts 32, is that at equal current the high-frequency voltage developed across the series capacitors 30, and hence on the whole loop antenna 6, relative to the surroundings, is low.

In this way, antenna shapes are enabled where a loop antenna 6 is formed by a single turn laid around a passageway, so-called walk-through antennas. Fig. 6 shows such a walk-through antenna arrangement. Arrow 22 indicates the direction of passage, which intersects the loop antenna 6. It will be immediately clear that the physical dimensions of the loop antenna must be so large as to allow persons to walk through the turn, and that in the use of high operating frequencies a solution such as indicated in this invention is necessary. In the use of such an antenna, the transponders to be detected or read out pass the plane of the turn, in which the magnetic field strength of the loop

antenna is maximal. This maximum field strength can now be much lower than in the case of loop antennas on the side of a passageway, as has been discussed with reference to Fig. 4. Risks of medical implants being influenced are thereby minimized, as are disadvantageous influences on the human body.

The invention is not limited in any way to the exemplary embodiments outlined hereinabove. Thus, the loop parts can be integrated with the interposed capacitors, yielding a cable which is reactance-free for one frequency. In principle, with this cable, loop antennas of unlimited dimensions can be constructed. Such a cable is shown in Fig. 7. The cable 40 comprises a multiplicity of conductive loop parts 32 and capacitors 34, with the conductive loop parts and the capacitors connected in series, such that two adjacent conductive loop parts are connected with each other through one of the capacitors. Further, in this example, a cable is provided with a sheath 42 of, for instance, plastic material in which the conductive loop parts and the capacitors are included.

Preferably, in the systems mentioned hereinbefore, the interrogation field has a frequency f greater than or equal to 8.2 MHz. More particularly, this frequency is greater than or equal to 13.56 MHz. However, other frequencies are also possible.

The system can be designed as a transmission system, known per se. It is also possible, however, that a system is designed as an absorption system for detecting the transponders.

In the example of Fig. 6, the system comprises an antenna configuration which functions both as transmitting antenna and as reception antenna. The antenna configuration in this example comprises a loop antenna 6, which comprises a single turn. Other variants, however, are also possible. Thus, it is possible that, for instance, the antenna configuration comprises a transmitting antenna, with a loop

antenna as has been discussed with reference to Figs. 5 and 6. The reception antenna can then consist of a separate, different type of loop antenna. It is also possible that the loop antenna, as shown in Fig. 5, comprises more than one turn. These turns can then be part of more extended antenna shapes. These can be understood to include, for instance, far-field balancing shapes, such as the 8-shaped antenna and the Maxwell pair (two loops arranged behind each other, fed in opposite phase). Also, other complex antenna shapes can be utilized, for instance by forming specific divisions of the magnetic field. The transponders can also be made of programmable design. Such variants are all understood to fall within the scope of the invention.

CLAIMS

1. A system for detecting and optionally communicating with transponders comprising a resonant circuit, such as antitheft transponders and identification transponders, comprising a transmitter and receiver device, an antenna configuration coupled with the transmitter and receiver device, comprising at least one loop antenna for radiating an electromagnetic interrogation field, and at least one transponder of which the resonant circuit is caused to resonate when the transponder is introduced into the interrogation field, the transmitter and receiver device further being arranged for detecting when the resonant circuit resonates, characterized in that the loop antenna is interrupted at a plurality of points by capacitors included in the loop antenna at said points, so that the loop antenna is made up of electrically conductive loop parts, with the loop parts and capacitors connected in series.

2. A system according to claim 1, characterized in that the electromagnetic interrogation field comprises a frequency f, while a loop part located between two capacitors has a dimension smaller than c/2*pi*f, where c is equal to the speed of light.

3. A system according to claim 2, characterized in that each of the loop parts located between two capacitors has dimensions smaller than c/2*pi*f.

4. A system according to any one of the preceding claims, characterized in that the electromagnetic interrogation field comprises a frequency f, while the capacitors have such capacitive values that at the frequency f the reactance of the capacitors and the reactance of self-inductances of the loop parts located between the capacitors compensate each other.

5. A system according to any one of the preceding claims, characterized in that the antenna configuration functions as a transmitting and reception antenna.

6. A system according to claim 5, characterized in that in use the loop antenna functions as transmitting and reception antenna.

7. A system according to claim 5, characterized in that the antenna configuration comprises at least one first loop antenna which, in use, functions as transmitting antenna and at least one second loop antenna which, in use, functions as a reception antenna.

8. A system according to any one of the preceding claims, characterized in that the system is designed as a transmission system.

9. A system according to any one of the preceding claims 1-7, characterized in that the system is designed as an absorption system.

10. A system according to any one of the preceding claims, characterized in that the loop antenna consists of a cable comprising a plurality of conductive loop parts and capacitors, with the conductive loop parts and the capacitors connected in series, such that two adjacent conductive loop parts are connected with each other through one of the capacitors.

11. A system according to claim 10, characterized in that the cable is provided with a sheath in which the conductive loop parts and the capacitors are included.

12. A system according to any one of the preceding claims, characterized in that the interrogation field has a frequency f greater than or equal to 8.2 MHz.

13. A system according to claim 12, characterized in that the interrogation field has a frequency f greater than or equal to 13.56 MHz.

14. A system according to any one of the preceding claims, characterized in that the loop antenna is designed as a walk-through antenna.

15. A transmitter and receiver device and an antenna configuration coupled with the transmitter and receiver device of the system according to any one of the preceding claims.

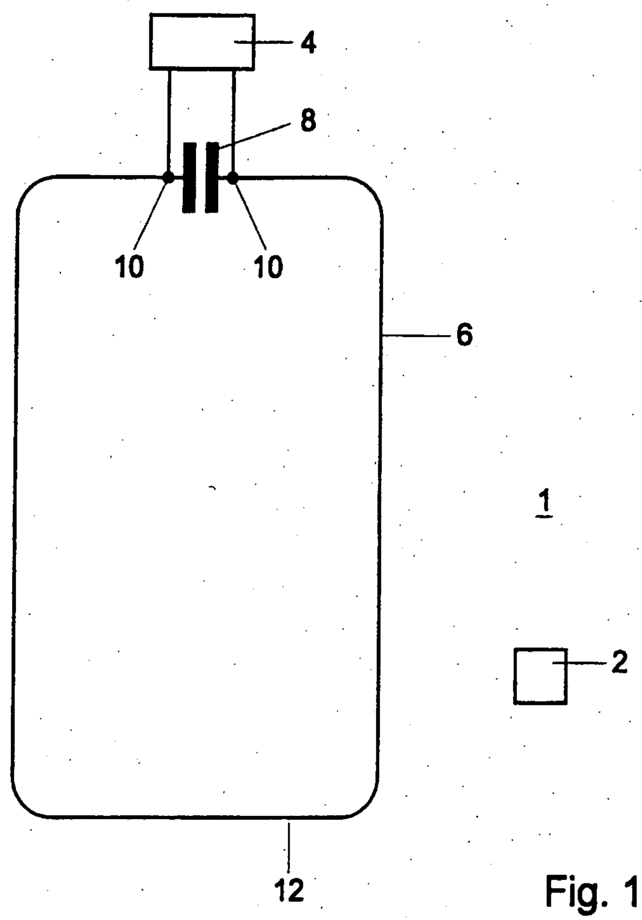

Fig. 1

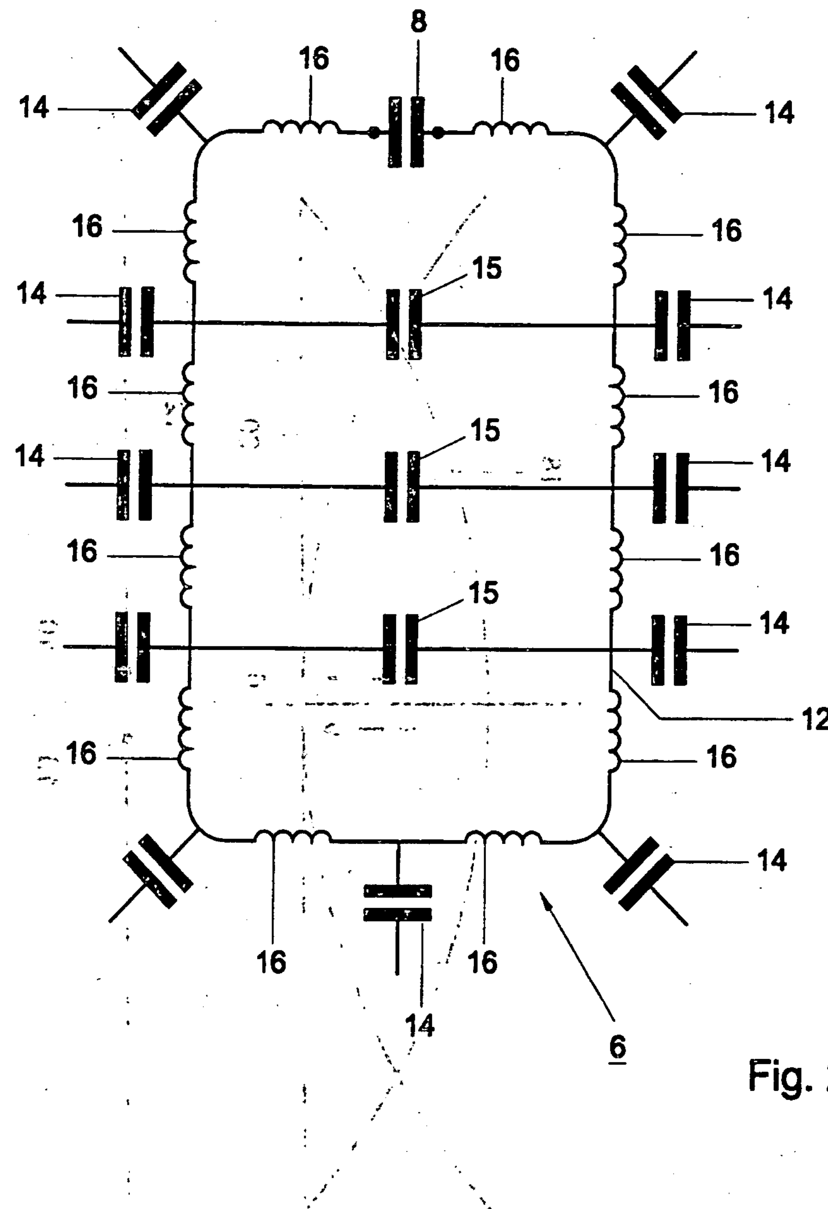
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Fig. 2

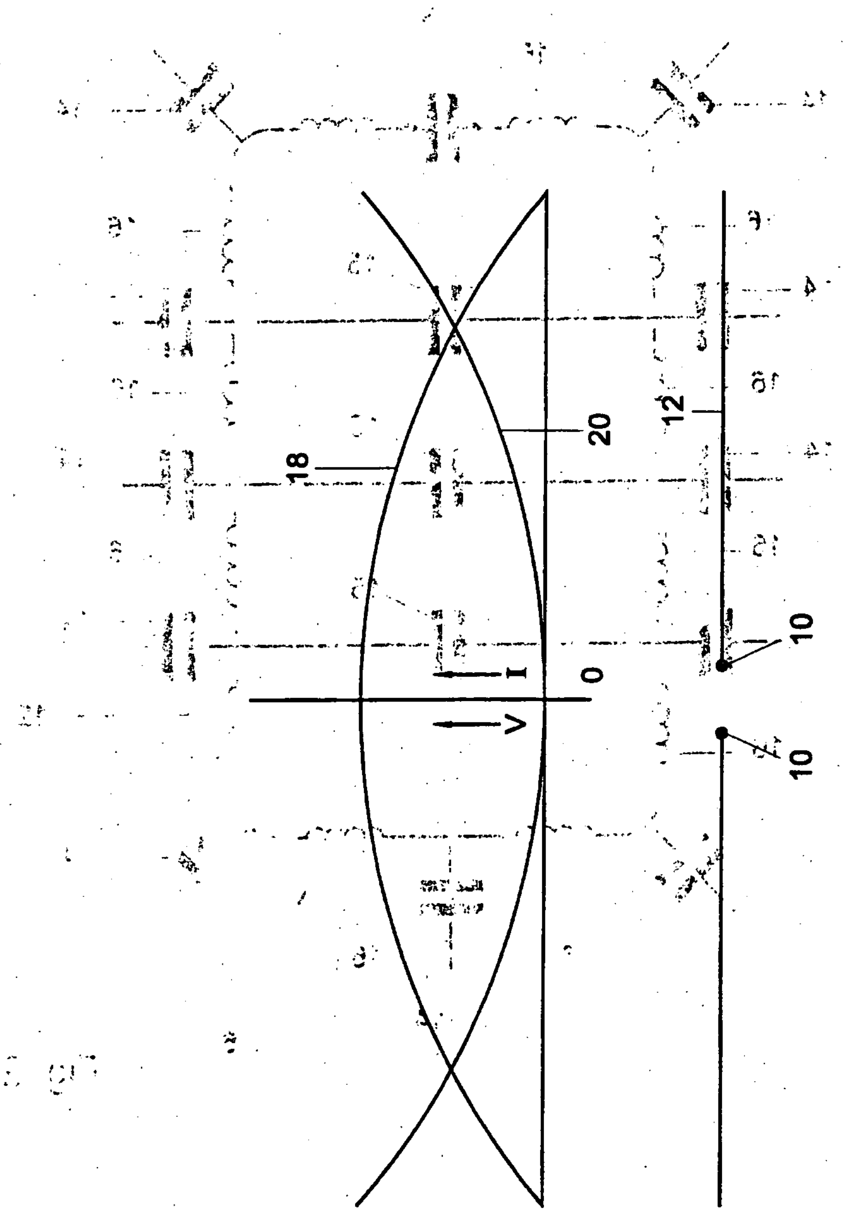

Fig. 3

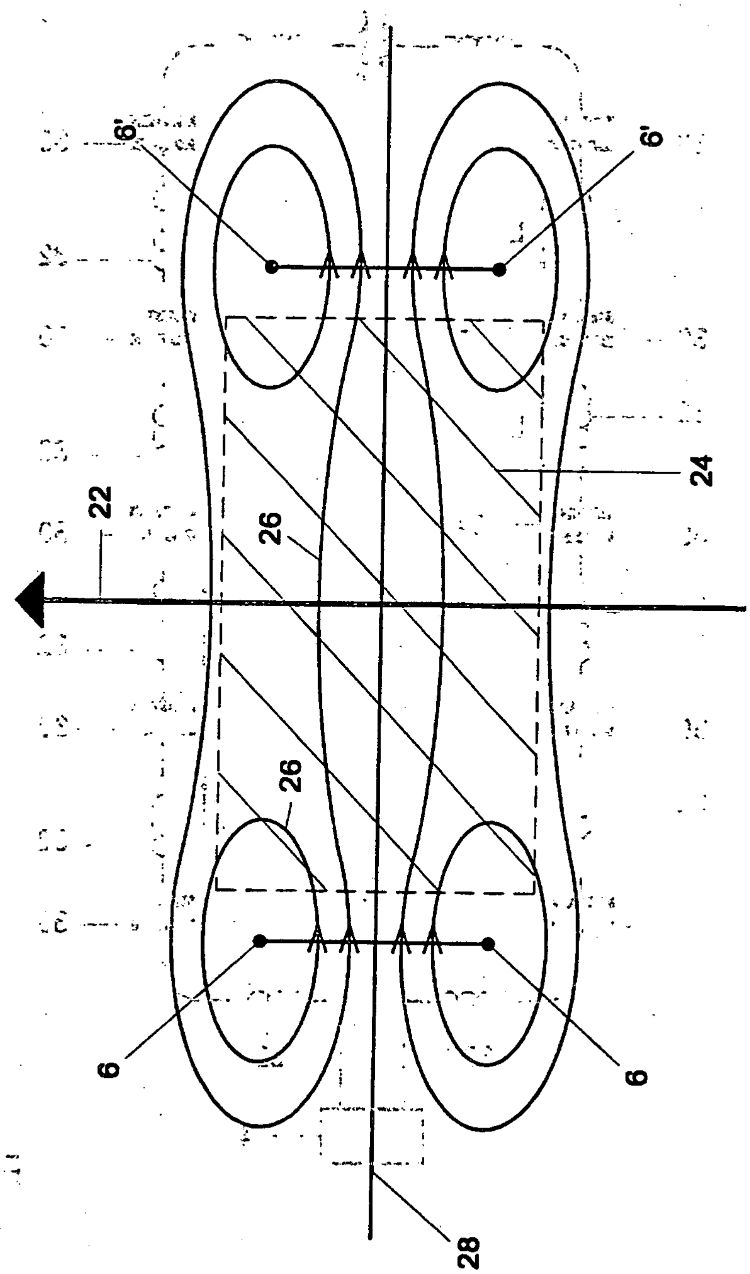

Fig. 4

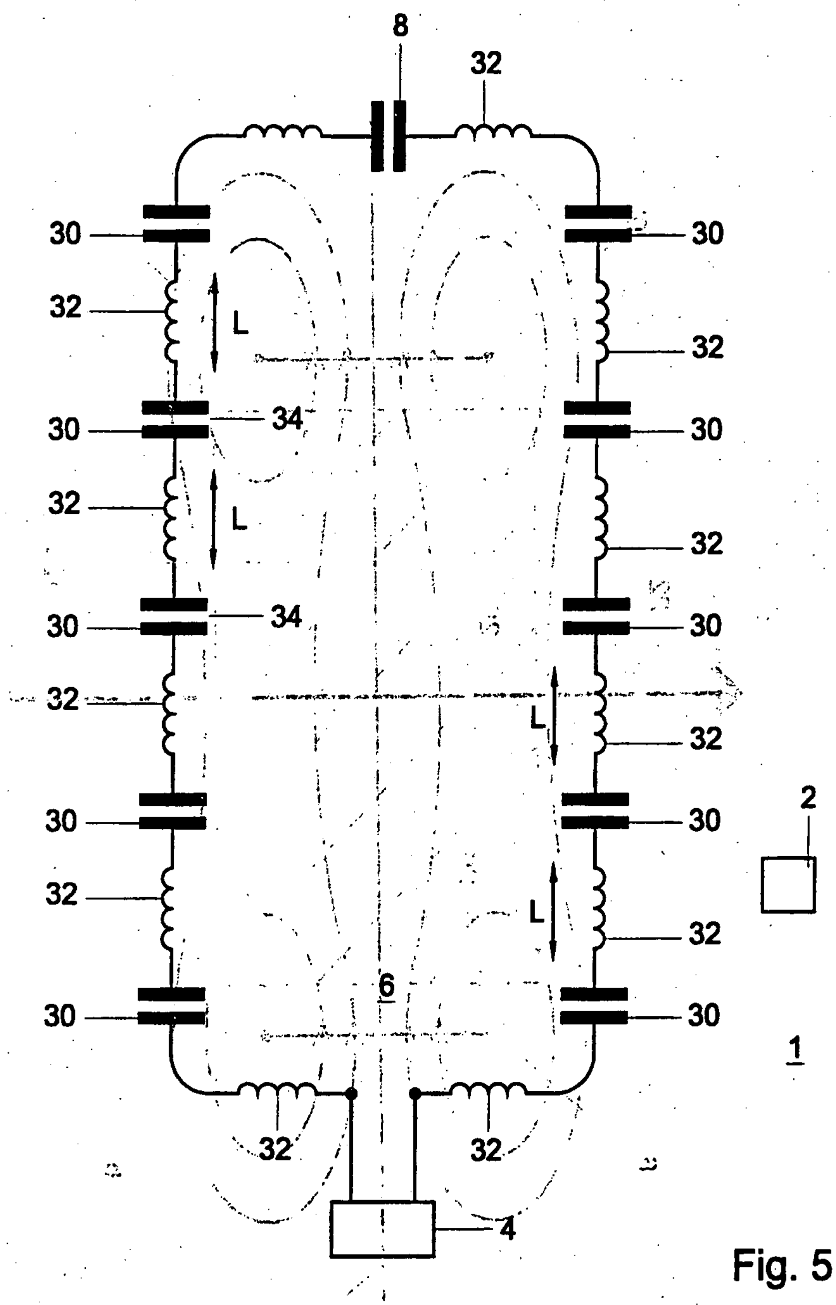
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Fig. 5

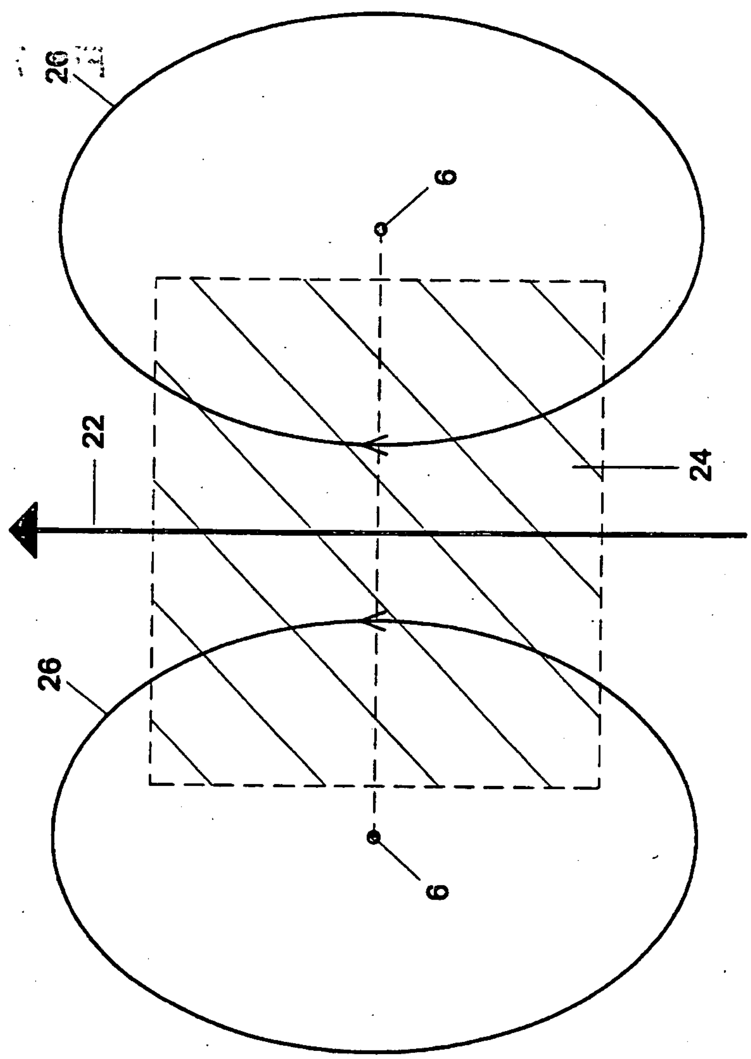

Fig. 6

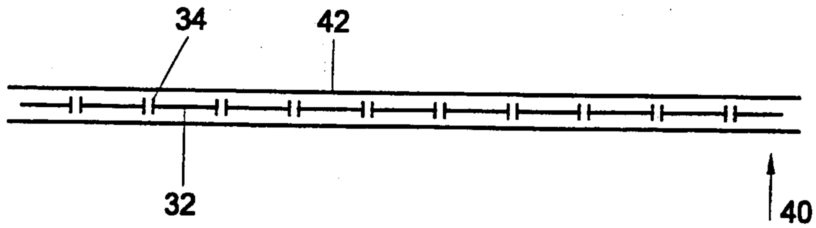

Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL 99/00675

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q7/00 H04B5/00 H01Q9/04 G08B13/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q H04B G08B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 92 17866 A (INTEGRATED SILICON DESIGN PTY) 15 October 1992 (1992-10-15) the whole document	1-10, 12-15
A		11
Y	NL 9 202 158 A (NEDAP NV) 1 July 1994 (1994-07-01) cited in the application the whole document	1-6
Y	WO 97 01197 A (MOTOROLA INC) 9 January 1997 (1997-01-09) page 3, line 30 -page 4, line 8; figure 1	1-6

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 January 2000	14/01/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Dooren, G

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL 99/00675

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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